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UNITED STATES ATOMIC ENERGY COMMISSION / PLOWSHARE PROGRAM

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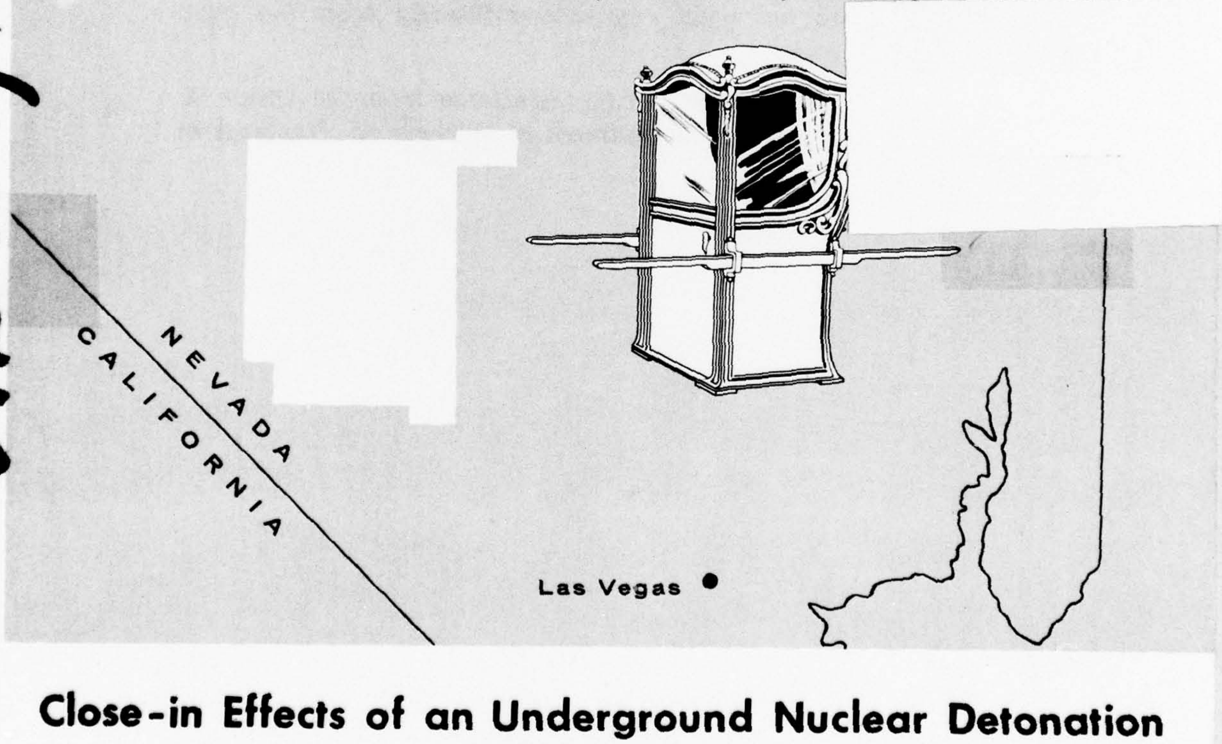

Close-in Effects of an Underground Nuclear Detonation on Vegetation

I. Immediate Effects of Cratering, Throw-out, and Blast

W. E. Martin

UCLA SCHOOL OF MEDICINE

ISSUED: MAY 1, 1963

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PROJECT SEDAN

PNE-228P

PROJECT 62.89

CLOSE-IN EFFECTS OF AN UNDERGROUND NUCLEAR DETONATION ON VEGETATION

I. IMMEDIATE EFFECTS OF CRATERING, THROW-OUT, AND BLAST

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ABSTRACT

Operation Sedan involved the detonation of a nuclear device at a depth of almost 650 ft. in the alluvium of Yucca Flat, Nevada. The preliminary results of studies dealing with the close-in effects of this detonation on vegetation have indicated the following: (1) Vegetation growing within a radius of 2000 ft. from ground zero was completely destroyed by cratering and blast. The original soil surface has been covered by a foot or more of radioactive throw-out. (2) In a band from about 2000 to about 5000 ft., the vegetation has been damaged by blast and throw-out. About 50 per cent of the shrubs present in this area before the detonation were blown away; but because of summer dormancy the percentage of plants actually killed cannot be determined until next spring when growth will be resumed. (3) From about 5000 to more than 10,000 ft. from ground zero, vegetation and soil were heavily blanketed by radioactive dust derived from the base surge cloud. This may have resulted in an early onset of summer dormancy, but no other damage was apparent.

The objectives of research now in progress are: (1) to estimate the extent to which vegetation has been destroyed or damaged by cratering, blast, and/or throw-out, (2) to study the re-establishment of vegetation in areas where the original vegetation was completely destroyed and the surface covered by a foot or more of radioactive throw-out, (3) to study the recovery of vegetation which was damaged but not destroyed by blast and/or throw-out, and (4) to study the effects, if any are detectable, of the exposure of plants to gamma radiation and to heavy

deposits of radioactive dust derived from the base surge cloud.

Objective number one should be met by the end of the growing season next year. Several years will be required to accumulate the data needed to meet objectives two, three, and four.

CLOSE-IN EFFECTS OF AN UNDERGROUND NUCLEAR DETONATION ON VEGETATION

I. Immediate Effects of Cratering, Throw-out, and Blast

INTRODUCTION

The general purpose of Project 62.89 is to study both the immediate and the long-term effects of an underground nuclear detonation (Operation Sedan) on vegetation within a radius of 18,000 ft. from ground zero. Preshot studies have been made to determine the composition and distribution of the major vegetation types within the study area. The major objectives of the program now in progress are: (1) to estimate the extent to which vegetation has been destroyed or damaged by cratering, blast, and/or throw-out, (2) to study the re-establishment of vegetation in areas where the original vegetation was destroyed and the original soil surface covered by a foot or more of radioactive throw-out, (3) to study the recovery of vegetation which was damaged but not destroyed by blast and throw-out, and (4) to study the effects, if any are detectable, of the exposure of plants to gamma radiation and to heavy deposits of radioactive dust derived from the base surge cloud. Studies of soil, soil-plant relationships, and the biological availability of certain radioisotopes have also been initiated, but these are subsidiary to the major objectives outlined above.

While this report provides a brief description of all the studies undertaken by Project 62.89, it deals chiefly with the preliminary results of studies made in connection with the first of the objectives

listed above. Because it is not now possible to distinguish between plants which are truly dead and those which are merely dormant, an accurate estimate of damage cannot be made until next spring. From one to several years may be required to accumulate the data needed to meet objectives two, three, and four above.

PROCEDURE

Sampling Stations. During the two weeks prior to Operation Sedan, on July 6, 1962, seven lines radiating from ground zero were surveyed, and sampling stations were established at intervals along each line. Each station was marked by a metal post and identified by a label indicating the line number and distance from ground zero. The arrangement of these lines and stations is illustrated in Figure 1.

Vegetation Surveys. Circular plots, 20 ft. in diameter, were established at or near each station marker. The center of each plot was marked by a wooden or metal post, and tallies were made to determine the number of individuals of each species occurring in the plot.

The data were summarized to indicate the frequency (%F)[1] and relative density (%D)[1] of the species populations comprising the herbaceous and shrubby vegetation within 18,000 ft. from Sedan ground zero.

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[1] $\%F = (P_1/P) \times 100$

$\%D = (N_1/N) \times 100$

Where: P = the number of plots examined
P_1 = the number of plots in which a given species occurred
N = the total number of plants counted
N_1 = the total number of individuals of a given species

This sampling procedure was repeated at selected stations during the last two weeks of August. It will be repeated again next year before the growing season begins, at more-or-less regular intervals throughout the growing season, and then once or twice per year for several years to come.

At all the stations on Line 16A (Fig. 1) and at selected stations on the other lines, total plant cover (C)[2] and the per cent coverage (%C)[2] of each species encountered were estimated by means of line-intercept studies. For this purpose three points per station were marked by wooden posts to indicate the centers of 20 ft. crosses (10 ft. in each of the cardinal directions).

The line-intercept distance for each plant encountered was measured and recorded according to species. The data thus obtained will provide a basis for estimating total plant cover and the per cent coverage of each species at various distances from ground zero.

The postshot collection of line-intercept data will not be made until next spring. Both preshot and postshot data will be reported later when comparisons can be made to derive an estimate of change in the species composition of vegetation as a function of distance from ground zero.

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[2] $C = (D_1/L) \times 100$

$\%C = (D_2/D_1) \times 100$

Where: L = the length of the line in inches
D_1 = the line-intercept distance of all plants encountered
D_2 = the line-intercept distance for a given species

Photography. Preshot and postshot photographs were taken on the ground at each sampling station and from the air of each line. These photographs have been and will continue to be useful in estimating the extent and kind of damage to vegetation, the limits and approximate depth of throw-out deposits, and the limits of heavy dust deposition from the base surge cloud. It is anticipated that further documentary photography may be required as these studies progress.

Dosimetry. On July 5th (D - 1 day) each station marker post beyond 1000 ft. from Sedan ground zero was equipped with two glass-chemical dosimeter packets capable of measuring cumulative gamma doses from 10r to 10^7r. One packet was centered on the post at a height of 2 inches above the soil surface, the other, at 36 inches.

Dosimeters were recovered on August 10th (D + 35 days) and sent to the manufacturer (E.G. & G.) for read-out. When the read-out data become available, we hope to be able to estimate the cumulative gamma doses to plants growing in the vicinity of station markers and to prepare contour maps which will indicate the cumulative gamma doses at 2 inches and at 36 inches above the ground throughout the major part of the study area.

Soils, Plants, and Animals. The continuing research program of the Environmental Radiation Division of the Laboratory of Nuclear Medicine and Radiation Biology (UCLA) is chiefly concerned with the physical and biological redistribution of radioisotopes occurring in areas contaminated by fall-out from nuclear detonations. It was therefore

appropriate in connection with this project and in connection with CETO Project 62.83 to investigate the pre- and postshot radioisotope content of soils, plants, and animals in the general vicinity of Sedan ground zero. Most of these data, when they become available, will probably be reported in connection with Project 62.83; but information concerning the radioisotope content of soils, and their uptake by plants, will be included in subsequent progress reports on Project 62.89.

RESULTS

Composition of the Vegetation. Preshot vegetation surveys have indicated that the area within 2500 ft. from Sedan ground zero (and for much greater distances to the south and west) was composed primarily of herbaceous plants. To the north and to the east, beyond 2500 ft., the vegetation was predominantly shrubby in composition.

Table 1 presents a summary of tallies from 35 circular plots located 750 to 2500 ft. from Sedan ground zero. As illustrated by these data and by Figure 2, the principal species of this area was *Salsola kali*, a robust and weedy annual. Note also, that shrubs are not abundant, but both *Atriplex canescens* and *Eurotia lanata* were found in more than half of the plots examined.

Salsola kali, *Hilaria jamesii*, *Mentzelia albicaulis*, and *Oryzopsis hymenoides* account for about 88 per cent of all the herbaceous plants counted. Because of its low frequency, Hilaria is probably the least characteristic of these abundant species. Oryzopsis, a stout bunchgrass, is the only perennial which occurs regularly and abundantly in this

vegetation. Because of its greater size and persistence throughout the year, Oryzopsis is generally more conspicuous than Mentzelia.

On line 11A to the south, this same kind of vegetation occurs out to 7000 ft. Thereafter, to the end of the line, it is similar in most respects but differs conspicuously in having a greater abundance of low shrubs. On line 20A to the west, the vegetation from 3500 to 12,000 ft. is herbaceous (Figure 3), but both Salsola and Oryzopsis are rare. The most abundant and characteristic species of this area are Erodium cicutarium and Bromus rubens.

Beyond 3000 ft. to the north and east of Sedan ground zero and beyond 12,000 ft. to the west, the vegetation is (or was) predominately shrubby in composition. Table 2 presents a summary of preshot tallies from 35 circular plots located at distances of 3000 ft. or more from Sedan ground zero.

Grayia spinosa and Coleogyne ramosissima are generally co-dominant in these areas, (Figure 4) but the composition of shrubby vegetation in northern Yucca Flat is actually quite variable from place-to-place. On lines 9A and 16A, for example, Coleogyne is more abundant than Grayia; but on line 12A, which lies between them and on the edge of a broad, shallow wash, both Grayia and Lycium andersonii are more abundant than Coleogyne. On the steeper terrain which characterizes the more distant parts of lines 6A, 16A, and 18A (Fig. 5), Coleogyne is by far the most abundant and occasionally, the only shrub species present.

Preliminary Estimate of Damage. Table 3 provides a preliminary estimate of the apparent reduction of shrub populations by blast and/ or throw-out associated with Operation Sedan. Some of the wooden and

metal posts used to mark the centers of circular plots were dislocated by blast or buried by throw-out. In these cases, there is some doubt as to whether or not pre- and postshot tallies were made at precisely the same places. Also, as indicated by discrepancies in the pre- and postshot tallies of plants growing in plots located 6000 ft. from ground zero, where apparently there was no dislocation of plot markers and no reduction of shrub populations, some allowance should be made for errors in counting shrubs.

In spite of their shortcomings, these data should provide a fair idea of the extent to which shrubs growing within a mile or so from ground zero were blown away by blast or buried by throw-out.

Preliminary Description of Zones Around Ground Zero. The description which follows is based primarily on a postshot reconnaissance in the vicinity of Sedan ground zero, a preliminary comparison of pre-shot and postshot photographs, and the postshot vegetation survey described in the preceding paragraph. The arrangement of zones and subzones described are diagrammed in Figure 6.[3]

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[3]The radial boundaries indicated for zones and subzones is only approximate, and the zones themselves are not symmetrical. The limits given in Figure 6 are fairly accurate for lines 6A, 9A, and 12A (See Figure 1). On line 16A and 18A, the boundary between zones A and B is located about 3000 ft. from ground zero. The boundary between zones B and C occurs on line 16A at a distance of about 5500 ft. from ground zero and on 18A, at about 7500 ft. On lines 11A and 20A, the boundary between zones B and C appears to occur at a distance of about 6000 ft.

(a) Zone A: Crater, Lip & Deep Throw-out Deposits. In this zone (Fig. 7), the vegetation has been completely destroyed by blast and/or throw-out deposition. The original soil surface has been covered by a foot or more of radioactive throw-out. The present surface is composed of this loose, unsorted alluvium and is barren of vegetation.

(1) Ground zero to 645 ft. The crater is nearly symmetrical and has an average diameter of 1290 ft. Its center lies 320 ft. below the original surface. About 7 million cubic yards of alluvium was excavated and most of this was deposited within a radius of 2000 ft. from ground zero to produce a bare surface (excluding the crater) of more than 250 acres.

(2) 645 to 1000 ft. The lip of the crater ranges in height from about 40 ft. on the east to about 75 ft. on the northwest. At the rim of the crater, the sides of the lip are nearly vertical. The slope of the outer face varies in relation to its height and is quite irregular. The average depth of throw-out at stations located 1000 ft. from ground zero is about 4 ft.

(3) 1000 to 2000 ft. The mantle or apron of throw-out extending beyond the lip of the crater is irregular in thickness, but it generally covers the original surface to a depth of one foot or more. All the station markers located less than 2500 ft. from ground zero were knocked down and partially or completely buried by throw-out. Many of the station markers beyond 2500 ft. were tilted, but only a few of them were buried by throw-out.

(b) Zone B: Shallow Throw-out & Blast Damage to Vegetation. In this zone (Figs. 8, 9, & 10), the vegetation has been damaged but not entirely destroyed by blast and/or throw-out missiles. The deposition of throw-out has been sufficient to produce an altered surface but not sufficient to cover all the original surface or to bury all the remnants of the original vegetation cover.

(1) 2000 to 3000 ft. In this area (Fig. 8), the vegetation has been severely damaged. More than 75% of the shrubs growing in this area (Table 3) were blown away. The visible remnants of shrubs are generally quite small, but some are large enough to hold small dunelets composed primarily of coarse sand.

Deposits of throw-out range from 12 to 6 inches but do not cover the original surface entirely. Probably the finer fractions of material deposited here immediately following the detonation have since been removed by wind erosion and deposited in areas farther to the northwest.

(2) 3000 to 4000 ft. In this tentative subzone (Fig. 9), at least 50% of the shrubs have been blown away (Table 3). The remnants of those which were not blown away are larger and more numerous than those of zone B-1. The dunelets which have formed on the leeward (northeasterly) sides of these remnants may be a foot or more in height and are composed primarily of fine sand and silt. Presumably all or most of this material was originally deposited in areas closer to ground zero and has been redistributed by strong southwesterly winds following the detonation.

(3) 4000 to 5000 ft. In this area (Fig. 10), blast damage has been somewhat irregular. Less than 25% of the shrubs have been blown away, but the overall damage to vegetation has probably been more extensive than indicated by the data currently available, (Table 3).

Only the throw-out consisting of small boulders can be distinguished from soil materials lying on the surface before the Sedan event. Wind blown deposits of very fine sand and silt are readily apparent but not deep. There has been some accumulation of this finer material around and under shrubs, but these incipient dunelets are generally no more than an inch or two in depth.

(c) Zone C: Radioactive Dust Deposits. Except on line 18A (Fig. 1) the vegetation surrounding stations located more than 5000 ft. from ground zero exhibits no visible signs of damage due to blast or throw-out. The vegetation and soil of this zone, which extends in most directions from about 5000 to about 10,000 feet from ground zero, was heavily blanketed by radioactive dust derived from the base surge cloud (Fig. 11).

Much of the original dust deposit has been removed from the area by wind erosion, but part of it has clung to the plants and soil surfaces, especially under shrubs. Plants exposed to the influence of this dust may have entered summer dormancy somewhat earlier than plants of the same species which were growing nearby but were not covered by dust. There is, however, no other visible evidence of damage to the plants in this zone.

exposed to the influence of these dust deposits may have entered dormancy somewhat earlier than plants of the same species which were growing nearby but were not covered with dust.

DISCUSSION

Phytogeography of Yucca Flat. Yucca Flat is a more-or-less typical desert basin. Phytogeographically, it is in the transition between the Great Basin to the north and the Mojave Desert to the south. About 100 miles to the north of Yucca Flat the desert shrub vegetation of the Great Basin is characterized by Sagebrush (*Artemisia tridentata*). That of the Mojave, some 40 miles to the south, is characterized by Creosote Bush (*Larrea divaricata*).

The top of Oak Spring Butte, about 3000 ft. higher and 5 or 6 miles to the north of Sedan ground zero, is occupied by a dense stand of *Artemisia tridentata*. The northernmost population of *Larrea divaricata* in this general vicinity is represented by a colony which extends to within a mile to the east and southeast of Sedan ground zero.

Most of the area between the Sedan site, the mountains to the north, and the hills to the east was occupied by desert shrub. This vegetation is apparently typical of that which occupied the entire northern rim of the Yucca Flat basin prior to the establishment of the Nevada Test Site. The area immediately surrounding Sedan ground zero and extending into the floor of the basin to the south and west was occupied by herbaceous vegetation. This vegetation, dominated by *Salsola kali*, is of recent origin, a product of prior disturbance by

nuclear and by high explosive detonations to the east, south, and west.

Effects of Operation Sedan. As indicated by our preliminary description of the zonation around the crater produced by Operation Sedan, the readily apparent effects of this detonation on nearby vegetation are largely attributable to the deposition of throw-out, to blast, and to the deposition of radioactive dust derived from the base surge cloud. In zone "A", ground zero to 2000 ft., the above-ground parts of plants were removed by blast and/or covered by throw-out. This denuded zone is characterized by a new surface composed of radioactive throw-out. In zone "B", 2000 to 5000 ft., the original shrub vegetation has been severely damaged, above-ground at least, by blast and by throw-out missiles. In zone "C", 5000 to 10,000 ft., the only apparent influence of Operation Sedan has been the deposition of radioactive dust derived from the base surge cloud.

Re-establishment of Vegetation in the Denuded Area. According to Shields and Wells (1962) the denuded portions of all ground zero areas in Yucca Flat up to the end of 1958 have "repeatedly produced abundant crops" of *Salsola kali*. In all probability, this will also occur in the denuded area, zone "A", surrounding the Sedan crater.

Our general objective in studying the re-establishment of vegetation on now barren surfaces composed of radioactive throw-out will be to learn what we can about the successional processes involved and how they may be influenced by the interaction of plants and environment.

What role is played by the substratum, its physical and chemical properties including radioactivity, in permitting or preventing the establishment of different plant species? How is the substratum changed by the development and/or persistence of pioneer vegetation, and how do these changes foster or contribute to subsequent changes in the composition and structure of vegetation which may develop later on the same area? In general, the questions to be asked and the problems to be studied are the same as those involved in other studies of plant succession. The main question, of course, is this: Does plant succession following environmental disturbance by a nuclear detonation differ in any significant respect from that initiated by less spectacular disturbances such as excavation by conventional means?

Recovery of Vegetation Damaged by Blast. Our current estimates of damage to vegetation should be improved when we are able to estimate the degree to which various species are able to recover from blast damage to their above-ground parts. The methods to be used in this endeavor are essentially the same as those employed by Palumbo (1962) in the South Pacific.

At the present time it appears likely that *Oryzopsis hymenoides* has been less severely damaged by blast than were the more brittle shrubs and annual herbs with which it was associated before the Sedan event. If this perennial bunchgrass has survived in areas where shrubs have not, it seems reasonable to predict that these areas may be characterized for some years to come by a ring of grass coincident with

the zone of most severe damage to shrubs.

Shields and Wells (1962) have observed grassy zones just beyond the perimeter of denudation around other ground zeros in Yucca Flat. They also observe that the most abundant bunchgrass in areas characterized by a compact substratum is Stipa speciosa while Oryzopsis humenoides is most abundant on loose, sandy substrata.

It should also be possible during the next growing season to check the Shields-Wells hypothesis that shrubs growing beyond the limits of visible blast damage to the above-ground parts may be injured or killed by the disruption of root systems by shock waves which travel through the ground. This kind of injury is most likely to occur in areas where the substratum is loose and sandy. Most of the substrata within 7000 or 8000 ft. from Sedan ground zero appear to exhibit these characteristics.

Potential Radiation Effects. As mentioned earlier, plans have been made to base estimates of the gamma doses received by the above-ground parts of plants on the measurements of cumulative gamma dose by dosimeters placed on station marker posts throughout the study area. It should be possible, after these data become available, to locate stations representing a gradient of cumulative gamma dose levels. Plants growing in the vicinity of these stations will be observed periodically throughout the growing season to detect any unusual responses in the development of meristems, growth rate, flowering, etc. which may be attributable to radiation. These plants will be compared with other plants of the same species growing in comparable habitats which were not exposed to unusual levels of gamma radiation. If specific effects are observed, it should be possible, using a rough contour map based on dosimeter measure-

ments, to estimate the frequency of such effects in areas characterized by different levels of cumulative gamma dose.

Need for Continuing Study. The data thus far obtained have provided the basis for a preliminary description of the immediate and readily visible effects of Operation Sedan on the vegetation and surface soil near ground zero. Early efforts to estimate the extent of damage to vegetation which was not completely destroyed have been hampered by the onset of summer dormancy. Difficulties caused by our inability to distinguish between plants which are truly dead and those which are merely dormant, and problems resulting from uncertainties as to the identification of damaged plants should be resolved during the next growing season.

Some progress can be made next year in regard to studies dealing with the establishment of vegetation on radioactive throw-out, the recovery of blast damaged vegetation, and the possible effects of radiation on plants exposed to heavy deposits of radioactive dust. All of these studies could and should be continued for a period of one to many years. If these studies are to have real significance in relation to Operation Sedan, it will be necessary to avoid the use of this area for further nuclear testing and to avoid its disturbance by other means for at least one year and for as many more years as may be feasible.

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3. R. F. Palumbo; "Recovery of the Land Plants at Eniwetok Atoll Following a Nuclear Detonation"; Radiation Botany 1:182-189, 1962.

Table 1. Composition of Herbaceous Vegetation. Based on pre-Sedan tallies of plants in 35 circular plots (20 ft. diameter) located 750-2500 ft. from ground zero on 7 lines radiating from ground zero (See Fig. 1). N = number of plants counted, P = number of plots in which species occurred, %D = per cent density, %F = frequency of occurrence in plots.

Plant Species *	N	P	%D	%F
SHRUBS	N	P	%D	%F
Atriplex canescens	98	23	50.8	65.7
Eurotia lanata	60	17	31.1	58.6
Lycium andersonii	11	8	5.7	22.9
Grayia spinosa	10	6	5.2	17.1
Chrysothamnus viscidiflorus	5	2	2.6	5.7
Ephedra nevedanesis	3	2	1.5	5.7
Franseria dumosa	3	2	1.5	5.7
Coleogyne ramosissima	1	1	.5	2.8
Hymenoclea salsola	1	1	.5	2.8
Menodora spinescens	1	1	.5	2.8
Shrub Totals:	193	---	99.9	---
HERBS	N	P	%D	%F
Salsola kali	7997	35	62.8	100.0
Hilaria jamesii	1470	9	11.6	25.7
Mentzelia albicaulis	1048	33	8.3	94.3
Oryzopsis hymenoides	626	34	5.0	97.1
Chaenactis spp.	588	30	4.7	85.7
Eriogonum spp.	386	25	3.0	71.4
Sitanion hansenii	182	21	1.4	60.0
Cryptantha spp.	114	14	.8	40.0
Machaeranthera spp.	81	13	.6	37.2
Euphorbia spp.	64	2	.5	5.7
Stephanomeria paniculata	37	11	.3	31.4
Astragalus lentiginosus	35	10	.2	28.6
Malocothrix glabrata	35	8	.2	22.9
Bromus rubens	32	3	.2	8.6
Stipa speciosa	16	8	.1	22.9
Sphaeralcea spp.	13	3	.1	8.6
Gilia spp.	10	8	.1	22.9
Phacelia spp.	5	3	--	8.6
Chenopodium atrovirens	3	2	--	5.7
Amsinckia tessellata	3	2	--	5.7
Lepidium fremontii	2	2	--	5.7
Coldenia nutallii	2	1	--	2.8
Oxytheca perfoliata	1	1	--	2.8
Herb Totals:	12,750	---	99.9	---

* Botanical nomenclature based on Beatley (1962)

Table 2. Composition of Shrubby Vegetation. Based on pre-Sedan tallies of plants in 35 circular plots (20 ft. diameter) located on line 6A from 3000 to 5000 ft., 9A from 5000 to 14,000 ft., 12A from 3500 to 6000 ft., 18A 4500 to 6000 ft., and 20A from 14,000 to 18,000 ft. from ground zero (See Fig. 1). N = number of plants counted, P = number of plots in which species occurred, %D = per cent density, and %F = frequency of occurrence in plots.

Plant Species * SHRUBS	N	P	%D	%F
Grayia spinosa	226	33	23.3	94.3
Coleogyne ramosissima	196	24	20.2	68.6
Hymenoclea salsola	123	20	12.7	57.2
Acamptopappus shockleyi	111	16	11.4	45.7
Eurotia lanata	96	20	10.0	57.2
Lycium andersonii	49	20	5.1	57.2
Ephedra nevadensis	43	18	4.4	51.4
Haplopappus cooperi	36	5	3.8	14.3
Menodora spinescens	33	7	3.4	20.0
Atriplex canescens	28	10	2.9	28.6
Franseria dumosa	9	2	1.0	5.7
Artemisia spinescens	5	4	.5	11.4
Chrysothamnus viscidiflorus	5	4	.5	11.4
Tetradymia axillaris	4	4	.4	11.4
Larrea divaricata	3	2	.3	5.7
Tetradymia glabrata	1	1	.1	2.8
Shrub Totals:	968	---	100.0	---

HERBS	N	P	%D	%F
Chaenactis spp.	1865	33	42.0	94.3
Bromus rubens	581	12	13.1	34.3
Mentzelia albicaulis	409	22	9.1	62.9
Salsola kali	271	18	6.0	51.4
Erodium cicutarium	257	2	5.7	5.7
Oryzopsis hymenoides	237	23	5.2	65.7
Eriogonum spp.	210	23	4.6	65.7
Sitanion hansenii	119	20	2.6	57.2
Amsinckia tessellata	105	17	2.3	48.6
Gilia spp.	86	17	1.8	48.6
Stipa speciosa	80	12	1.7	34.2
Oxytheca perfoliata	73	16	1.5	45.7
Cryptantha spp.	70	16	1.5	45.7
Hilaria jamesii	65	2	1.4	5.7
Malocothrix glabrata	34	7	.7	20.0
Astragalus lentiginosus	22	7	.4	20.0
Phacelia spp.	14	3	.2	8.6
Machaeranthera spp.	9	6	.1	17.1
Chorizanthe thurberi	8	3	.1	8.6
Stephanomeria paniculata	7	6	.1	17.1
Sphaeralcea spp.	2	2	---	5.7

(continued)

Table 2 (Cont'd)

HERBS:

Lepidium lasiocarpum	1	1	---	2.8
Tridens pulchellus	1	1	---	2.8
Herb Totals:	4,449	---	100.1	---

*Botanical nomenclature based on Beatley (1962)

Table 3. The apparent reduction of shrub populations by blast and/or throw-out. Based on a comparison of preshot and postshot tallies of shrubs in circular plots (20 ft. diameter) located at distances of from 2000 to 6000 ft. to the northwest, north, and northeast of Sedan ground zero.

LINE	Distance between plot and Ground Zero								Total
	2000	2500	3000	3500	4000	4500	5000	6000	
			(Preshot Shrub Tallies *)						
6A	21	13	38	55	78	35	37	29	306
9A	5	13	16	11	13	24	26	31	139
12A	6	20	14	27	26	27	23	33	176
16A	13	2	41	26	26	22	35	33	198
Totals:	45	48	109	119	143	108	121	126	819
			(Postshot Shrub Tallies)						
6A	0	3	6	24	32	30	31	30	156
9A	0	2	8	7	5	24	24	36	106
12A	0	4	6	24	16	21	20	27	118
16A	0	0	8	6	24	20	29	34	121
Totals:	0	9	28	61	77	95	104	127	501
Per cent Reduction	100	81	74	49	46	12	14	0	39

*Includes some shrubs which were either dead or dormant at time of survey.

FIGURE CAPTIONS

1. Layout of lines and sampling stations around Sedan ground zero.

2. Herbaceous vegetation. The dominants here are _Salsola kali_ and _Oryzopsis hymenoides_. Scooter crater is visible in the background.

3. Herbaceous vegetation. The dominants here are _Erodium cicutarium_ and _Bromus rubens_. Sedan ground zero is at drilling rig in the distance.

4. Shrubby vegetation. _Grayia spinosa_ and _Coleogyne ramosissima_ are codominants on the lower slopes and on the sandy soil of washes.

5. Shrubby vegetation. _Coleogyne ramosissima_ is the major dominant of compact alluvium on the upper slopes. Grayia may be present but not abundant.

6. Diagram of zones around Sedan ground zero.

7. Zone A: Vegetation within 2000 ft. of ground zero (a) was completely destroyed and the surface covered by a foot or more of throw-out (b). The lip of the crater in this view is about 75 ft. higher than the original surface.

8. Zone B-1: Between 2000 and 3000 ft., the vegetation (a) has been severely damaged by blast and/or throw-out (b). Where the original surface was not deeply covered by throw-out, some remnants of shrubs and occasional remnants of herbaceous plants are visible.

9. Zone B-2: Between 3000 and 4000 ft., the remnants of shrubs are relatively numerous and may hold dunelets composed primarily of fine sand. These occur on the northeasterly sides of shrub remnants and are in line with prevailing winds from the southwest.

10. Zone B-3: Between 4000 and 5000 ft., blast damage to shrubs has been moderate. Throw-out and/or wind blown deposits of fine sand and silt are readily apparent, but these are usually no more than an inch or two in depth.

11. Zone C: Between 5000 and 10,000 ft., there is little or no evidence of blast damage, but deposits of dust from the base surge cloud are readily evident on the vegetation and on the soil.

Figure 1. LAYOUT OF LINES AND SAMPLING STATIONS AROUND SEDAN GROUND ZERO. Line numbers are followed by the letter A. Azimuth is indicated by AZ. The intervals between sampling stations are as follow: from 1000 to 5000 ft., 500 ft.; from 5000 to 10,000 ft., 1000 ft.; and from 10,000 to 18,000 ft., 2000 ft. Dashed lines indicate paved roads while dotted lines are used for dirt roads and trails. Other craters noted on the sketch are: (a) Teapot, (b) Jangle, and (c) Scooter.

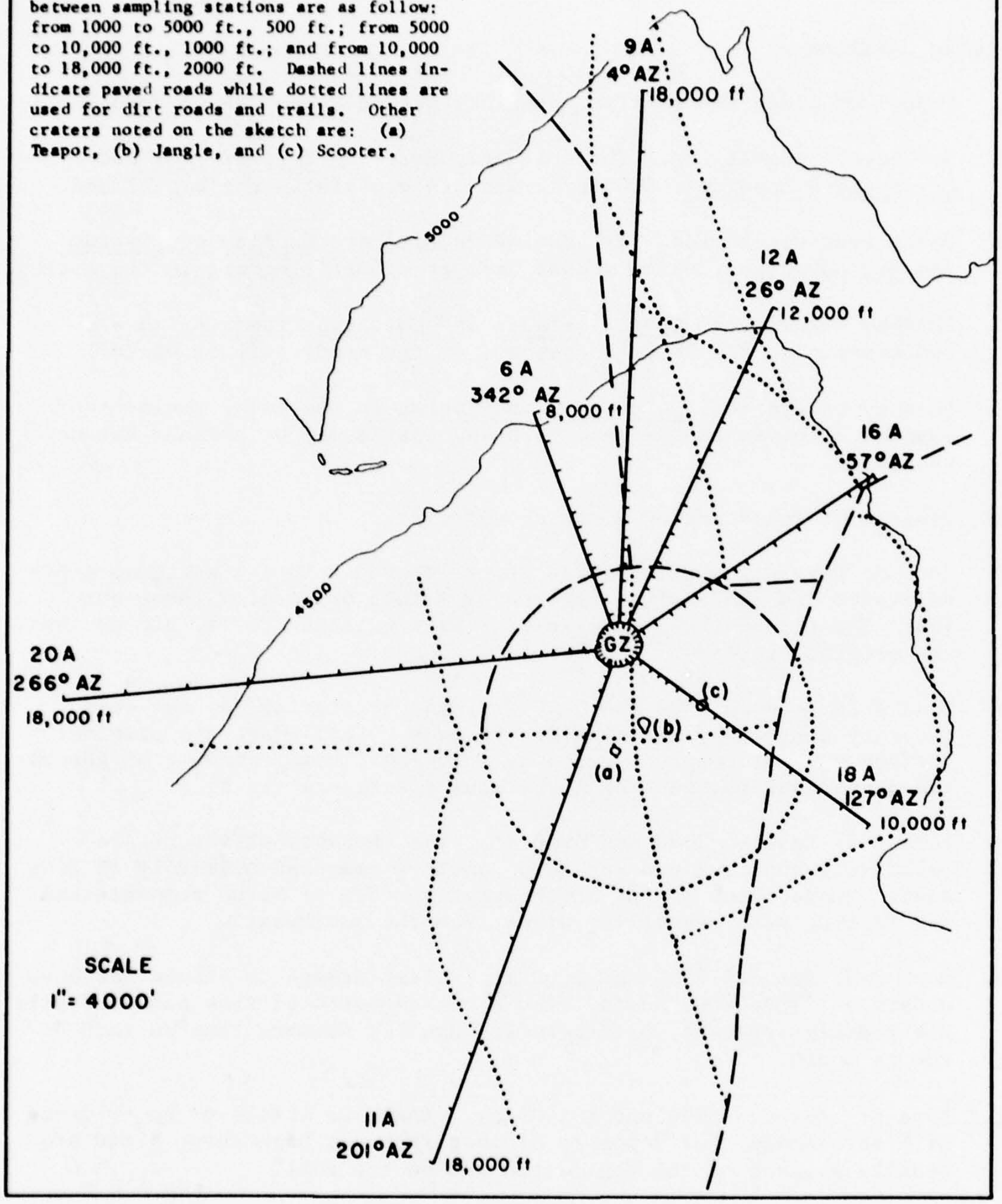

Figure 2 18A-2000-A 6/22/62

Figure 3 20A-5500-T 6/23/62

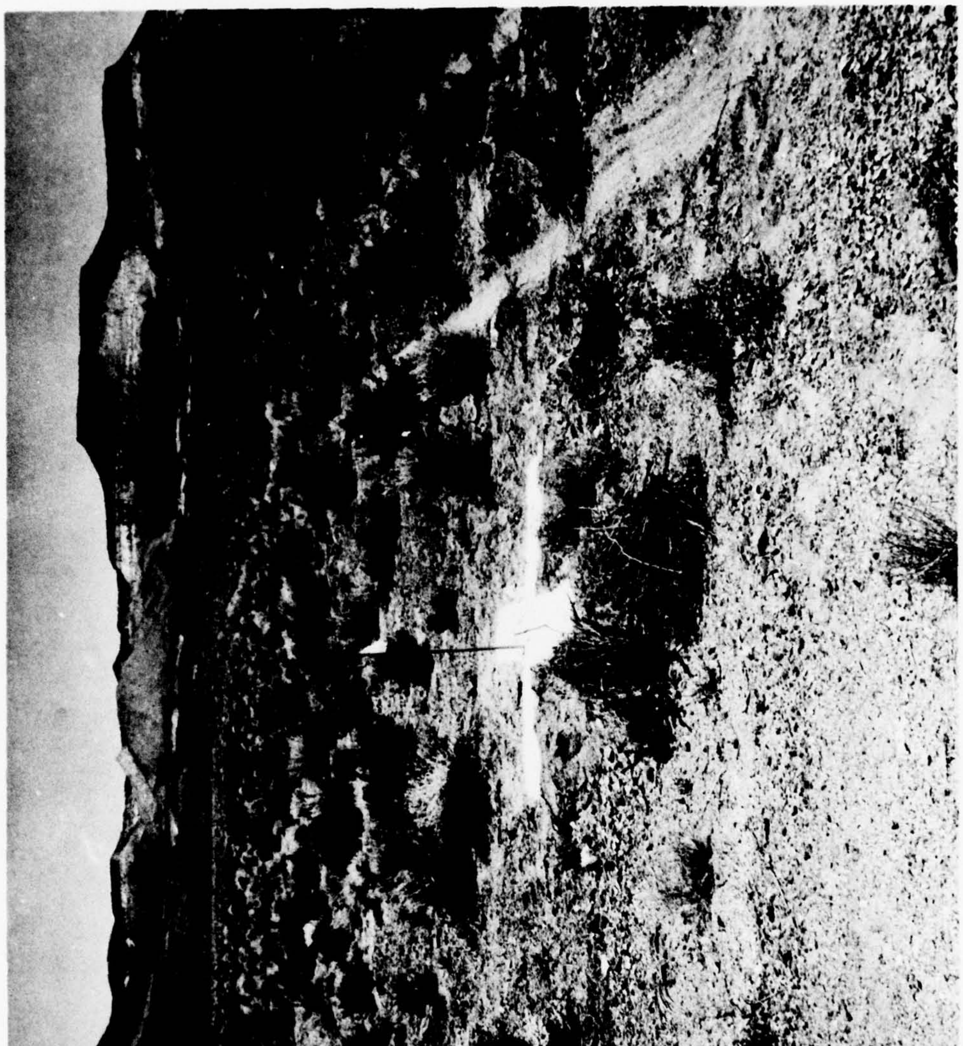

Figure 4 6A-4000-A 6/25/62

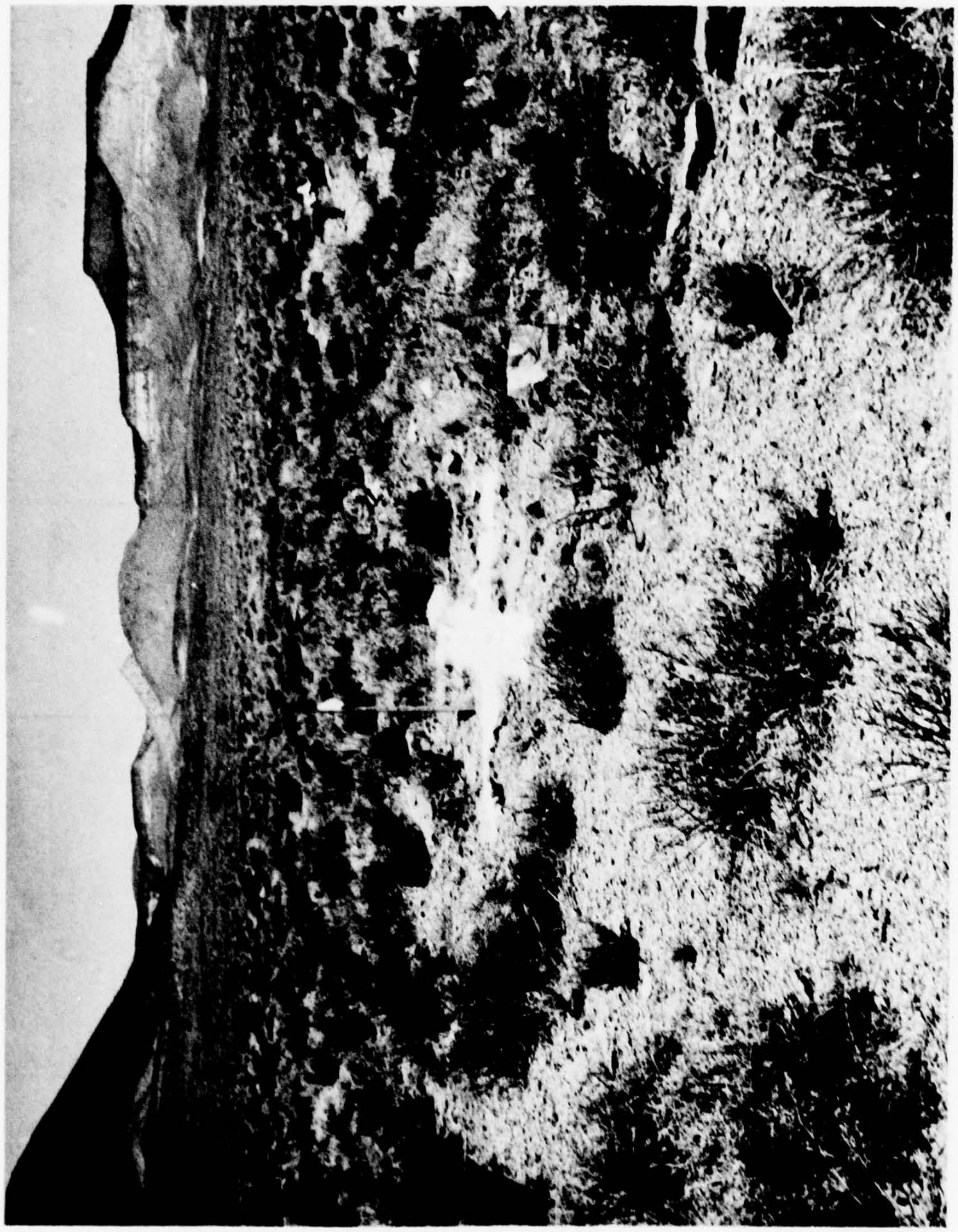

Figure 5   6A-8000-A   6/25/62

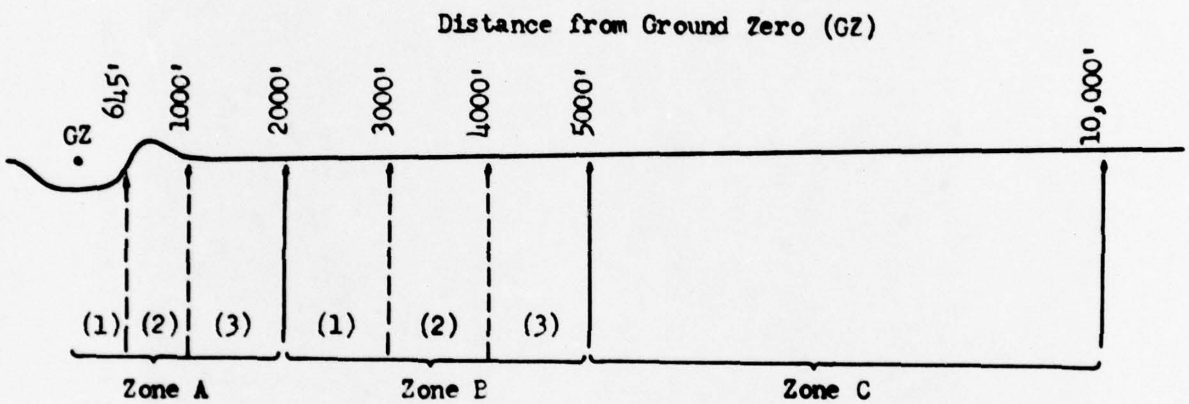

Figure 6. Diagram of Zones Around Sedan Ground Zero.

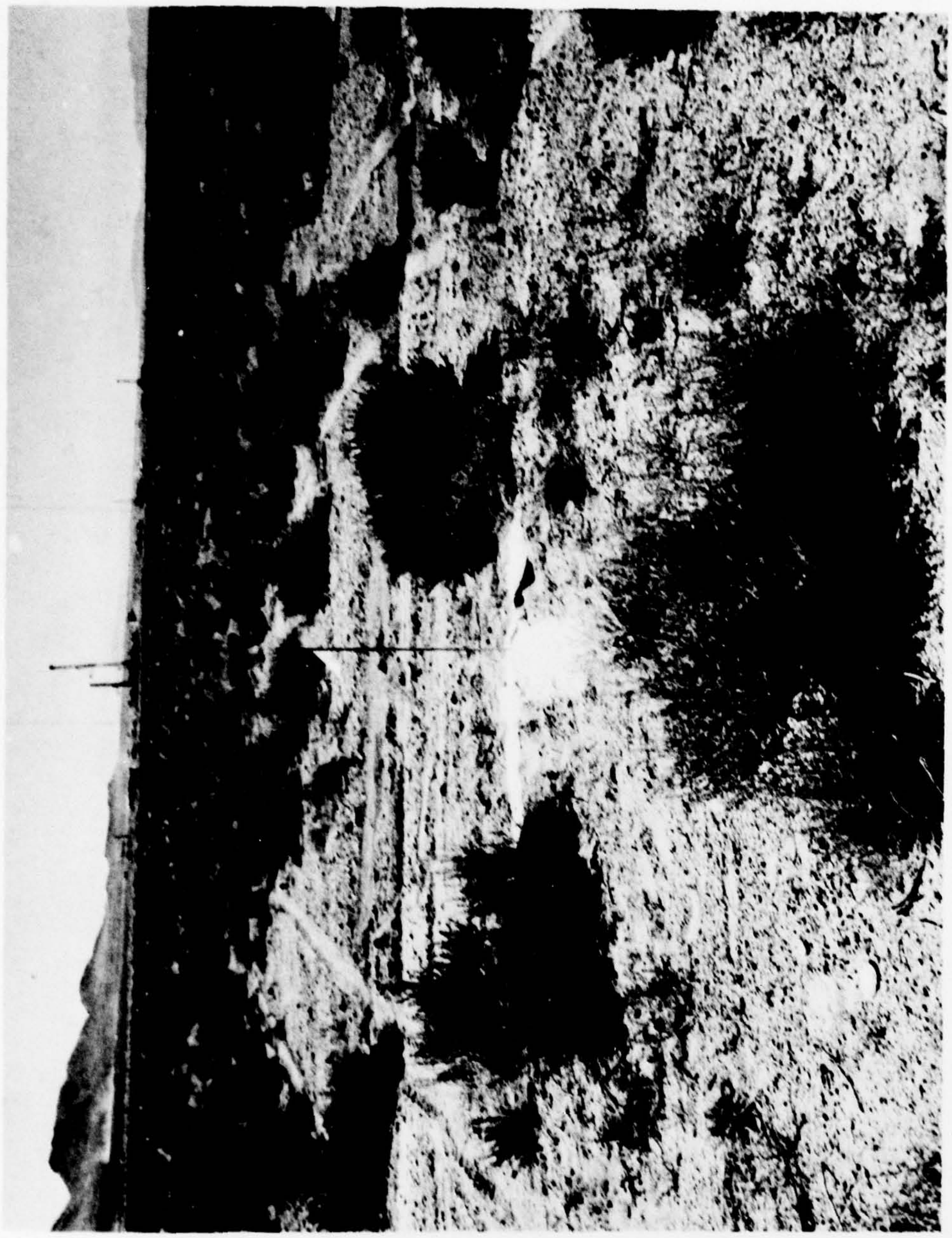

Figure 7a 6A-2000-T 6/25/62

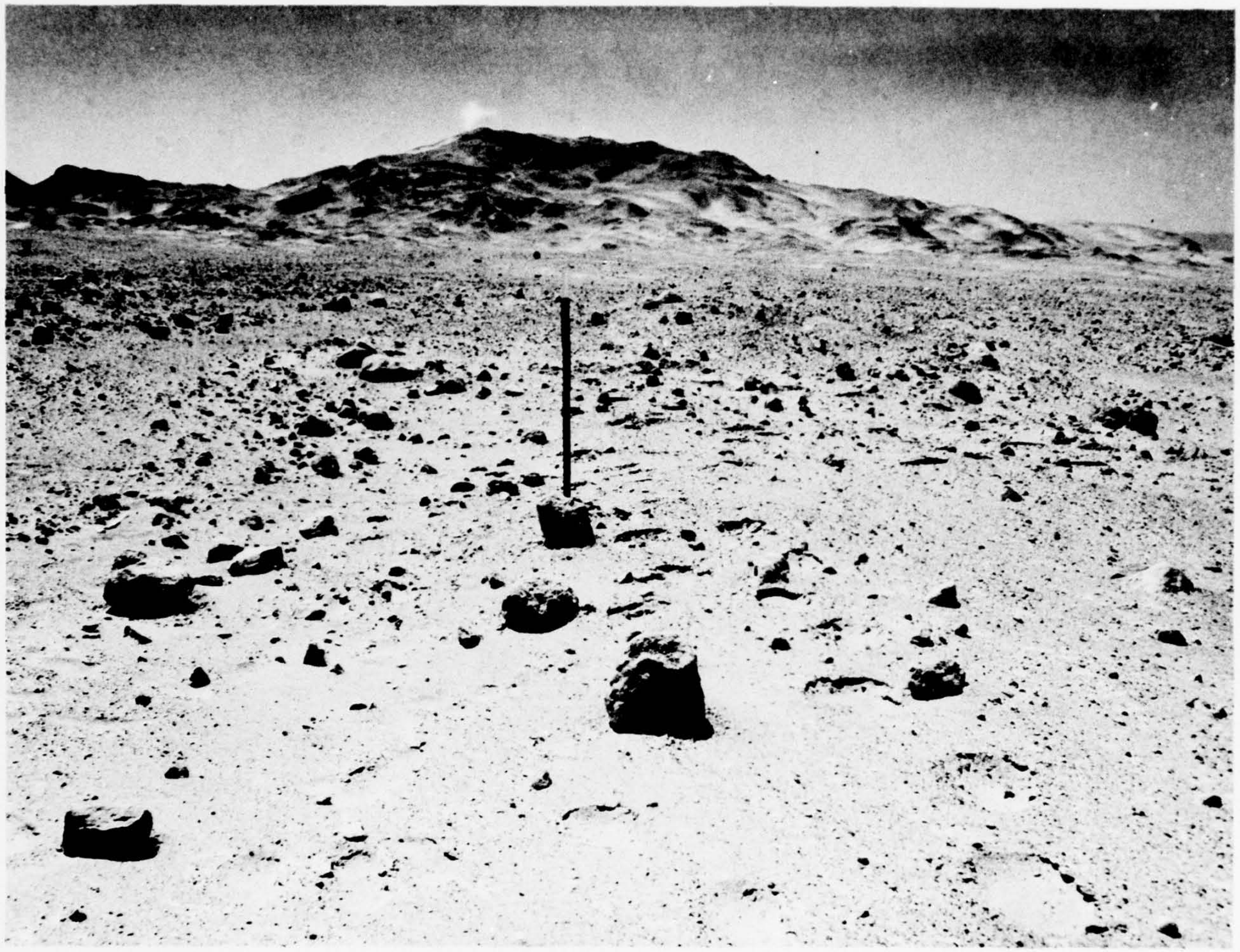

Figure 7b   6A-2000-T   8/22/62

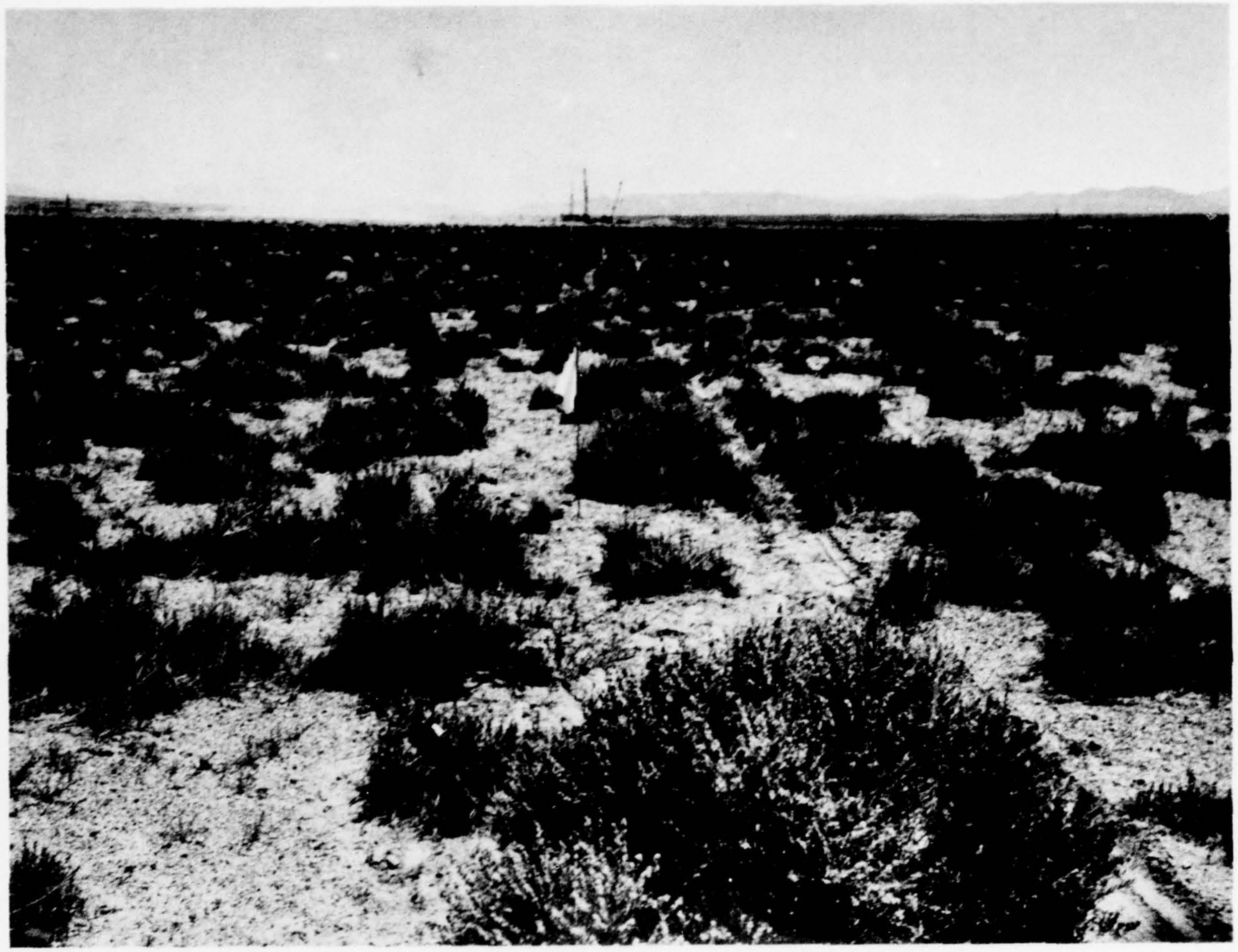

Figure 8a 9A-2500-T 6/19/62

Figure 8b 9A-2500-T 8/21/62

Figure 9a 9A-3500-T 6/19/62

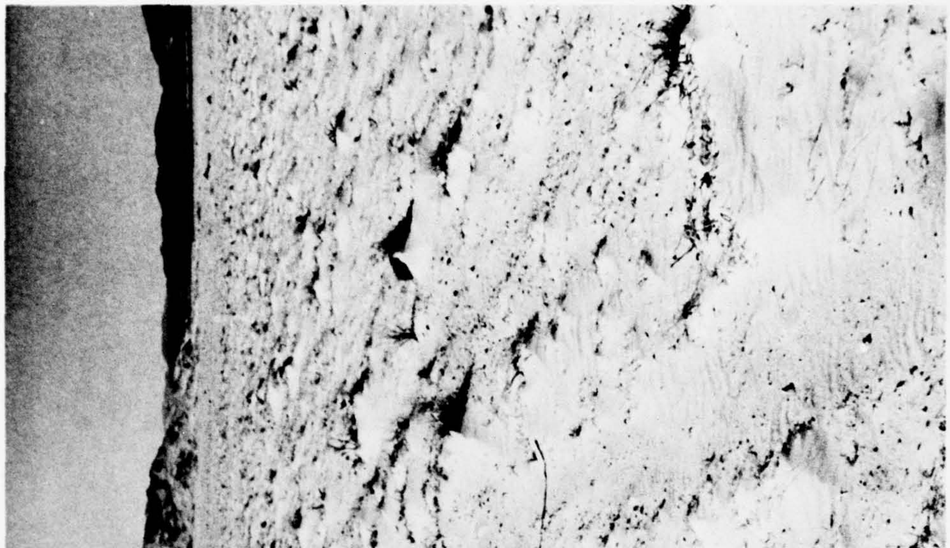

Figure 9b 9A-3500-T 8/21/62

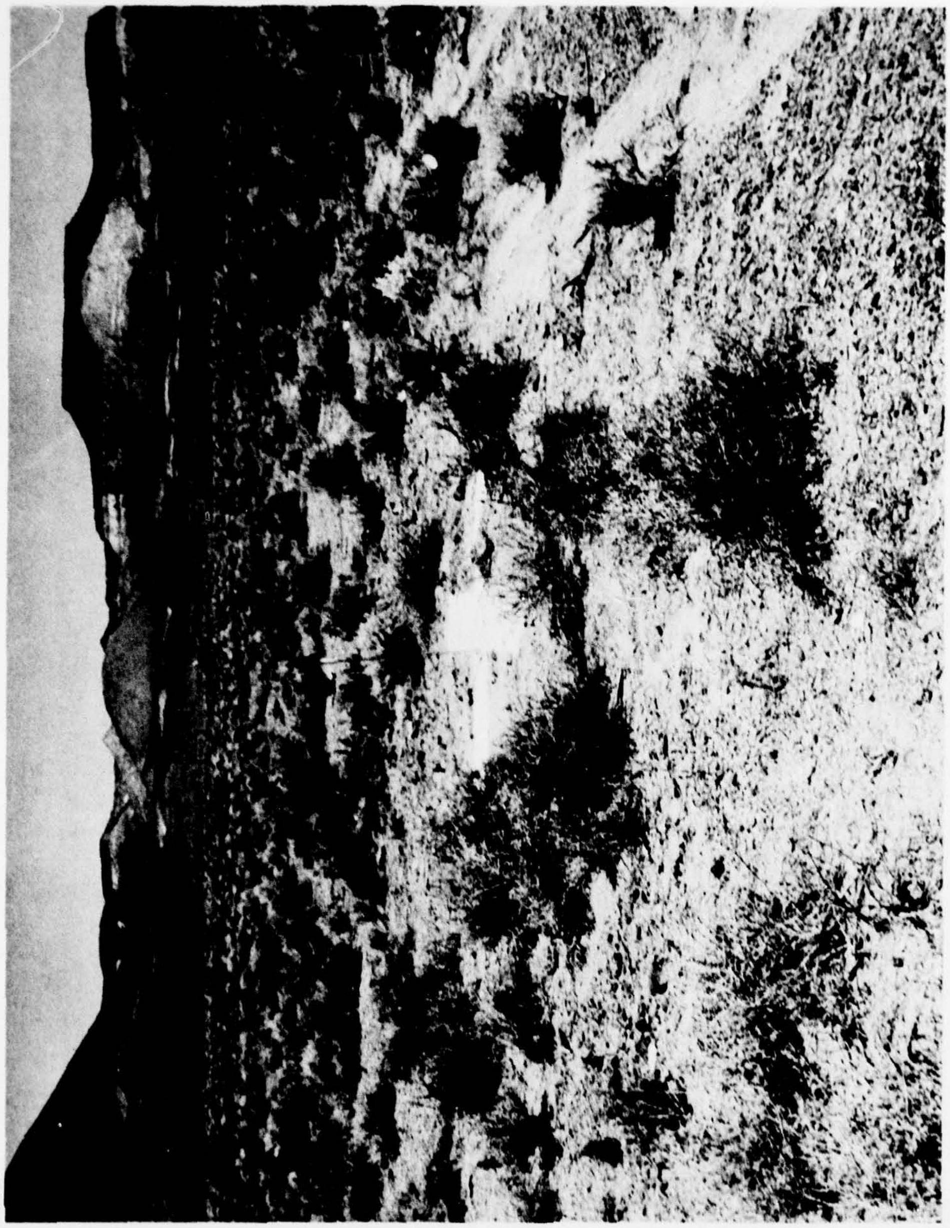

Figure 10a 6A-5000-T 6/25/62

Figure 10b 6A-5000-T 8/22/62

Figure 11a 16A-7000-A 6/21/62

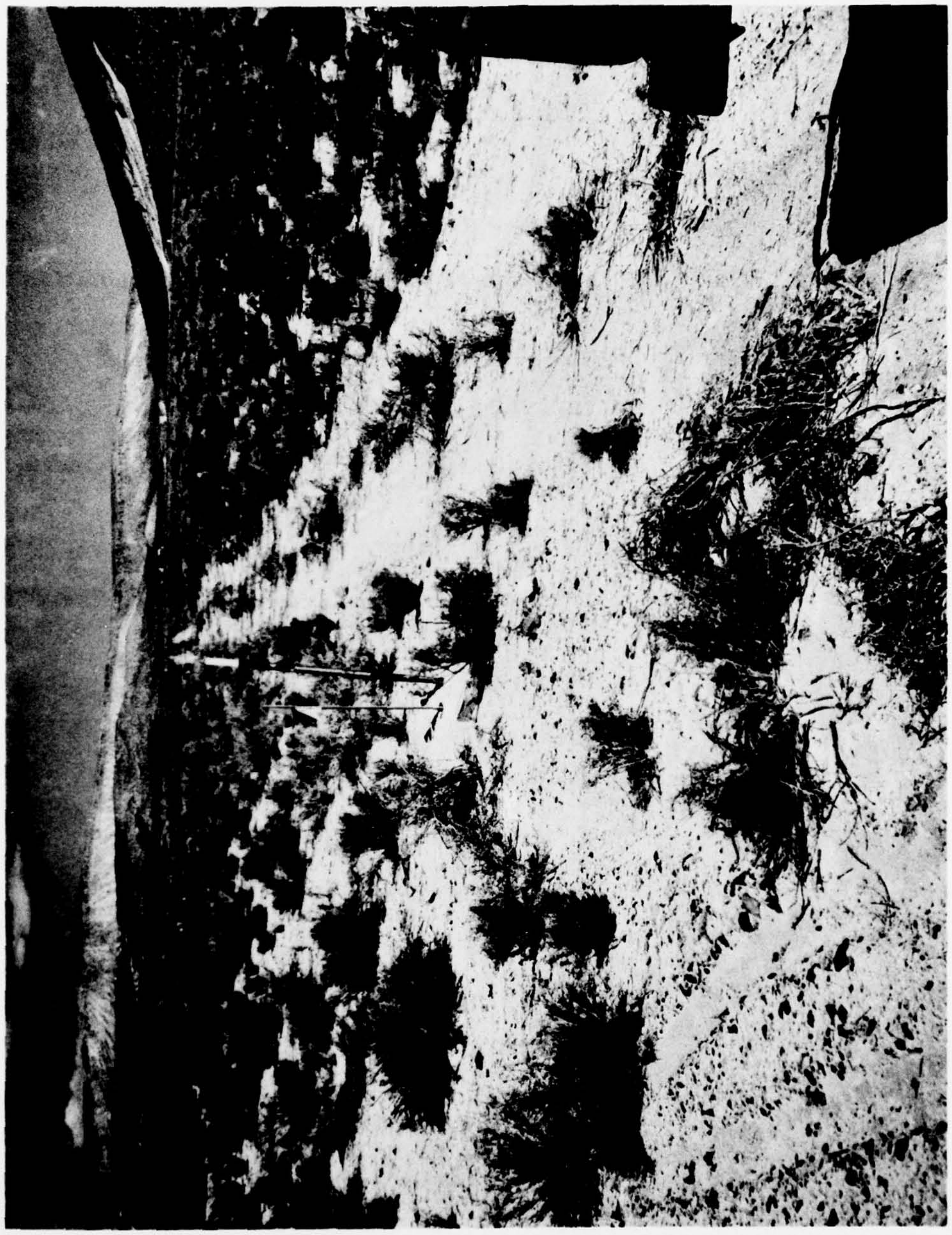

Figure 11b 16A-7000-A 8/23/62

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AEC/USBM	204F	Structural Survey of Private Mining Operations
FAA	205F	Airspace Closure
SC	211F	Close-In Air Blast From a Nuclear Event in NTS Desert Alluvium
LRL-N	212P	Scientific Photo
LRL	214P	Fallout Studies
LRL	215F	Structure Response
LRL	216P	Crater Measurements
Boeing	217P	Ejecta Studies
LRL	218P	Radioactive Pellets
USGS	219F	Hydrologic Effects, Distance Coefficients
USGS	221P	Infiltration Rates Pre and Post Shot
UCLA	224P	Influences of a Cratering Device on Close-In Populations of Lizards
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TECHNICAL REPORTS SCHEDULED FOR ISSUANCE BY AGENCIES PARTICIPATING IN PROJECT SEDAN

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LRL	231F	Rad-Chem Analysis
LRL	232P	Yield Measurements
EGG	233P	Timing and Firing
WES	234P	Stability of Cratered Slopes
LRL	235F	Seismic Velocity Studies

DOD REPORTS

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USC-GS	213P	"Seismic Effects From a High Yield Nuclear Cratering Experiment in Desert Alluvium"
NRDL	229P	"Some Radiochemical and Physical Measurements of Debris from an Underground Nuclear Explosion"
NRDL	230P	Naval Aerial Photographic Analysis

ABBREVIATIONS FOR TECHNICAL AGENCIES

STL	Space Technology Laboratories, Inc., Redondo Beach, Calif.
SC	Sandia Corporation, Sandia Base, Albuquerque, New Mexico
USC&GS	U. S. Coast and Geodetic Survey, San Francisco, California
LRL	Lawrence Radiation Laboratory, Livermore, California
LRL-N	Lawrence Radiation Laboratory, Mercury, Nevada
Boeing	The Boeing Company, Aero-Space Division, Seattle 24, Washington
USGS	Geological Survey, Denver, Colorado, Menlo Park, Calif., and Vicksburg, Mississippi
WES	USA Corps of Engineers, Waterways Experiment Station, Jackson, Mississippi
EGG	Edgerton, Germeshausen, and Grier, Inc., Las Vegas, Nevada, Santa Barbara, Calif., and Boston, Massachusetts
BYU	Brigham Young University, Provo, Utah
UCLA	UCLA School of Medicine, Dept. of Biophysics and Nuclear Medicine, Los Angeles, Calif.
NRDL	Naval Radiological Defense Laboratory, Hunters Point, Calif.
USPHS	U. S. Public Health Service, Las Vegas, Nevada
USWB	U. S. Weather Bureau, Las Vegas, Nevada
USBM	U. S. Bureau of Mines, Washington, D. C.
FAA	Federal Aviation Agency, Salt Lake City, Utah
REECO	Reynolds Electrical and Engineering Co., Las Vegas, Nevada

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